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Fruit sensory characterization of four Pescabivona, white-fleshed peach [Prunus persica (L.) Batsch], landraces and correlation with physical and chemical parameters

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Abstract – **Introduction**. *Pescabivona* is the name of an autochthonous peach [*Prunus persica* (L.) Batch] population of the Middle-West of Sicily. In a previous work, this product was submitted to chemical analyses, while in this paper, sensory evaluation is considered. **Materials and methods**. Samples of *Pescabivona* landraces were harvested during all the harvest season. A trained panel outlined the sensory profiles and the data were processed by ANOVA and Principal Component Analysis (PCA). A correlation between sensory analysis and instrumental data was finally carried out. **Results and discussion**. The results demonstrated a high standard of quality for all the landraces, with some differences in aroma intensity and in some other parameters, with sweetness and aroma being highly correlated with overall liking. PCA did not clearly separate the different landraces as they have the same origin. Some correlations between sensory analysis and instrumental data were verified. The sensory liking was correlated with the main ripeness parameters, as well as with the pulp firmness. **Conclusion**. The data obtained contribute to outline a complete fruit profile for product comparison and shelf-life monitoring. As previously verified for chemical parameters, sensory evaluation indicates a substantial similarity among the landraces. The good agreement between sensory evaluation and composition makes sensory analysis a precious tool to assess quality of *Pescabivona* landraces.

Keywords: *Pescabivona*; white flesh peach; sensory analysis; sensory and physical and chemical attribute relationships; parameter correlations; peach composition.

1. Introduction

Peach and nectarine fruit [*Prunus persica* (L.) Batch] are the second most important fruit crop in the European Union (EU) after apple [1].

Sensory quality attributes of fruits play a crucial role in consumer satisfaction [2, 3] as well as in the approval of agricultural and food-chain subjects [4]. Although the quality of peaches can be successfully determined by physical and chemical analyses, sensory analysis is another useful approach to the evaluation of the fruit quality [3, 5–7]. In fact, if compared to physical and chemical analysis, sensory analysis has the remarkable advantage of selecting the attributes most affecting the consumer satisfaction [8]. These kinds of protocols are also progressively more used in breeding, in testing new cultivars (cvs.), and in storage practices [9].

In making decisions, consumers are primary influenced by the appearance of peach (visible quality) [10]. However, other sensory parameters are involved in the preference of consumers. These parameters are often scarcely present in the peaches currently available on the market [2, 8]. Among these parameters, peach flavor results from a delicate balance of sweetness, sourness, aroma, and astringency, apart from additional physical attributes such as pulp texture. Taste is related to water-soluble compounds, while smell is elicited by volatile compounds. Balanced degree of sweetness and sourness is considered as a consistent characteristic with a positive correlation with consumers' preference [2, 3, 8].

Astringency is generally considered as a negative sensorial trait, indicating unripe fruits [11, 12]. The relationships between the sensory and physical and chemical attributes of peach fruit are still matter of investigation. An earlier study showed as the sensory evaluation of peaches did not match well with main quality chemical factors, not allowing a classification into groups [13]. However, the difficulty in correlating analytical and sensory measurements is well-known and it is attributed to the high variability of fruits [14].

More recently, Esti et al. [7] proposed that the chemical characteristics of fruits could be used as effective comparative indicators of sensory quality. In particular, the relationships between sugars, non-volatile acid content and some sensory attributes (sweetness and sourness) were studied on different peach and nectarine cvs.

On the contrary, Colaric et al. [6] showed that titratable acidity (TA) and soluble solid content (SSC) could not be substituted for sensory evaluation of perceived sweetness and sourness due to the complexity of the latter attributes. They demonstrated that sugars/organic acid ratio and levels of organic acids have significant impacts on perception of sweetness. Moreover, these authors asserted that aroma could be influenced by fixed compounds, as well. Total organic acids, sucrose, sorbitol, and malic acid influenced smell perception, while malic/citric acid ratio, total sugars, sucrose, sorbitol, and malic acid affected taste.

Different authors assert that an individual sensory attribute is better defined by a set of different molecules, which are involved in different measure in the attribute perception, rather than a single class of substance as sugars for sweetness and organic acids for sourness [15].

In Sicily, as well as in other territories, environmental and human selection yields an interesting germplasm of *Prunus persica* (L.) Batsch [16, 17]. Among this germoplasm, *Pescabivona,* also known as “Pesca di Bivona” [18], is a collective name of autochthonous landraces [19] characteristic of the countryside around Bivona, in the Middle-West of Sicily. Nowadays, *Pescabivona* identifies four landraces called: Murtiddara (also called Primizia Bianca), Bianca, Agostina, and Settembrina [20]. They are characterized by different ripening times from the end of June (Murtiddara) up to the end of September (Settembrina).

These landraces were recently characterized by their physical and chemical profiles composition [21], showing a general homogeneity of composition and giving evidence of quality in terms of high pulp firmness, sugar and lactone content, along with a balanced SSC/TA ratio. However, no study about sensory evaluation of *Pescabivona* is reported. For this reason, sensory traits of the four *Pescabivona* landraces were investigated.

This research was aimed at: i) gaining information on *Pescabivona* sensory characteristics by a trained panel of judges; ii) establishing correlations between sensory analysis, and physical and chemical data. The results can also contribute to provide a complete fruit profile for product comparison and shelf-life monitoring, to give support to growing activities based on local germplasm as a source of valuable quality features, to support the achievement of PGI according to the EU rules, and to provide information for marketing activity of the product, in terms of immediate language to the consumers.

2. Materials and methods

2.1. Sampling

Samples of the four *Pescabivona* peach landraces (Murtiddara, Bianca, Agostina, and Settembrina) were collected inside the growing area around Bivona (Sicily, Italy, lat. 37.619, long. 13.438) during all the harvest season.

Details on the characteristics of the orchards and the description of agronomic and growing techniques were already reported [21].

The peaches were collected at the ripening stage “ready-to-eat”. Fruits were evaluated by means of change in ground color from green to yellow and fruit size corresponding to AA caliber (diameter from 73 to 80 mm, and circumference from 23 to 25 cm). Since peach quality shows variability within tree [22], fruit sampling was standardized under the following condition: middle vigor trees, rootstock GF 677, south exposure, external part of the tree.

A gross sample of 40 peaches was handpicked for each landrace by different trees. The samples were carefully put in refrigerated polystyrene boxes and they were immediately airmailed to the laboratory for sensory analysis. At the same time, a gross sample of 54 peaches was collected for each landrace and destined to physical and chemical analysis only [21].

Panel sessions were performed the day after each harvest. A few minutes before the session, once reached the room temperature, the peeled samples were cut in pieces and gently mixed to reduce the variability.

2.2. Sensory analysis

2.2.1. Panel of judges

The panel of judges, recruited by Organizzazione Nazionale Assaggiatori di Frutta (O.N.A.Frut.), encompassed twelve subjects. All the judges have successfully attended a training course and they perform sensory analysis for several years. The training activities include weekly sessions to improve perception sensitivity and evaluation of individual descriptors, in addition to evaluation of different fruit varieties.

These subjects, including males and females, aging from 20 to 60, were selected on the basis of the general guidance [23].

Their experience was considered suitable as for the senses of taste, smell, and visual and for general rules of sensory analysis, as reported in the standard methods [23, 24].

2.2.2. Sensory evaluation on sliced fruits

A descriptive analysis [25] was carried out by the trained panel group in individual sensory booths, to avoid exchange of opinions or any other conditioning. Each panelist was asked to evaluate visual, olfactive, and gustative attributes by recording the intensity on a 10-cm structured line scale anchored at each end [25, 26]. Eleven sensory attributes related to color, texture, odor, (retronasal) aroma, and taste of the analyzed samples were evaluated: pulp ground color, presence of red veins, fibrousness, hardness, juiciness, intensity of smell, sweetness, sourness, bitterness, and aroma. Pulp ground color and presence of red veins were visually evaluated. Finally, each panelist was asked to express the overall liking to provide the potential consumer acceptance.

2.2.3. Sensory evaluation on entire fruits

In order to prevent a possible influence of fruit appearance on sensory evaluation, the descriptive evaluation on the whole fruit was carried out at the end of each panel session. Judges were called to evaluate the geometric shape, symmetry of shape, peel ground color, percentage and kind of peel over color, and intensity of smell.

2.3. Physical and chemical analysis

Physical and chemical profiling of the samples were described in a previous paper [21]. Herewith a list of the determination is simply reported:

a) color and color distance analysis for peel and pulp color were determined as CIE coordinates (L*, a*, and b*) [27] by a reflectance chromameter;

b) physical and chemical analysis such as weight, pulp firmness, pH, soluble solid content (SSC), and titratable acidity (TA) were determined by electronic balance, fruit pressure tester, refractometer, pH-meter, and titration, respectively; SSC/TA ratio was also calculated;

c) organic acids and sugars were determined by HPLC after extraction;

d) flavan-3-ols and hydroxycinnamic acids were determined on peel and pulp by UV/Vis spectrophotometer after extraction;

e) antioxidant capacity was determined on peel and pulp by ABTS assay after extraction;

f) lactones was determined by GC after extraction and concentration.

2.4. Statistical analysis

Analysis of variance (ANOVA), Tukey test [28], linear regression analysis, and principal component analysis (PCA) were performed using Statistica version 8.0 software (Stat 180 Soft Inc., Tulsa, USA).

3. Results and discussion

3.1. Sensory analysis on sliced fruits and one-way ANOVA

The results and statistical analysis concerning the sensory analysis are reported in Table 1.

Among the texture descriptors, fibrousness and juiciness showed statistically significant differences ($p \leq 0.01$), while hardness did not, notwithstanding Settembrina had a hardness mean value slightly higher than the other landraces.

Fibrousness had the highest scores for Agostina and intermediate for Bianca and Settembrina, whereas Murtiddara showed the lowest values. Probably for this reason, Murtiddara was the landrace with the highest juiciness scores followed by Bianca and Agostina, while Settembrina was judged as the least juicy.

All the landraces were described as very fragrant, and ANOVA did not show any statistical difference.

Taste descriptors, conversely, allowed a more remarkable discrimination among the landraces. Settembrina was the sweetest peach ($p \leq 0.05$), whereas the lowest scores were recorded for Murtiddara. Consistently, Murtiddara came out as the sourest peach ($p \leq 0.01$), followed by Bianca and Settembrina, while Agostina was by far the least. Finally, bitterness stressed the differences ($p \leq 0.001$) among the landraces. Bianca was judged as the bitterest peach (2.63), while Murtiddara and Agostina reached score remarkably lower (0.50 and 0.71). Also aroma (retronasal perception) showed some differences among landraces. The most aromatic landrace was Settembrina, followed by Agostina and Murtiddara, while Bianca came last.

All samples were described as white pulp peaches, while the presence of red veins near the stone was registered for all the landraces, except Murtiddara. Moreover, the sample of this landrace showed a large variability. In fact, 73 % of the fruits did not show any veins, 18 % showed red veins near the stone, and 9 % showed red veins widespread in the pulp.

3.2. Sensory analysis on whole fruits

Geometrical shape was described as spheroidal for all landraces except for Bianca that was indicated as oblate-spheroidal. Only Murtiddara was described as without shape symmetry.

Peel ground color was yellow-green for Murtiddara and Bianca, white-green for Agostina, and white for Settembrina, while peel over color was red for all the landraces.

All the whole unpeeled peaches were described as markedly smelling. Murtiddara and Bianca were described as highly fragrant, while Agostina scored 42 % of high cases, 33 % of medium ones, and 25 % of low ones. Finally, Settembrina was considered for 58 % as high cases and 42 % as medium ones.

3.3. Principal component analysis

PCA was applied to the autoscaled data to detect the most important variables for determining their structure. The first three principal components (PCs) showed eigenvalues > 1.0 [29] explaining 65.8 % of the total variance.

The plot of the PC1 (31.66 % of total variability) vs. PC2 (19.02 % of total variability) (Fig. 1) showed as the samples of the different landraces did not clearly separate into different clusters. This means that there is not a clear segregation of the landraces according to their organoleptic characteristics, as proposed by Crisosto et al. [15] for peach and nectarine cvs., thus confirming a general homogeneity of *Pescabivona* landraces. More in detail, samples are scattered on the plane, with a tendency of clusterizing for some landrace. For example, Settembrina is grouped on PC1, while Murtiddara makes a loose cluster on PC2. This behavior should confirm a close relation among the different landraces, and the fact that they have the same geographical origin. In other terms, the differences are more apparent than real. On the other hand, similar considerations were achieved also for physical and chemical determinations [21].

Murtiddara (M) had almost always positive values on PC1 due to high juiciness and low fibrousness. On the contrary, Agostina (A) and much more Settembrina (S) showed negative values on PC1 due to low juiciness and high fibrousness, but also aroma and overall liking. However, three samples of Agostina are characterized by positive values on PC1 and PC2 and three samples of Settembrina by negative values on PC1 and PC2 probably due to high juiciness and low fibrousness along with low intensity of smell and sweetness for Agostina samples and to high hardness, sourness, and bitterness for Settembrina samples.

It is interesting to notice as fibrousness and juiciness texture descriptors had high weights on PC1 (Fig. 2), with opposite signs, the former negative and the latter positive, while hardness is orthogonal to both.

PC3 (15.12 % of total variability) did not show any loading value > 0.5. The scores (Fig. 3) confirmed the scatter of the Bianca samples, but also Murtiddara, along this axis, while Agostina and Settembrina were located in a more limited area.

3.4. Correlation among the sensory descriptors

Correlation matrix of the sensory analysis data set was reported in Table 2. As observed for PCA and as expected, fibrousness and juiciness were negatively correlated ($p \leq 0.001$). The texture descriptors did not evidence any correlation.

It was noteworthy that the overall liking was highly correlated not only with sweetness ($|r| = 0.48$; $p \leq 0.001$), but also and much more with aroma ($|r| = 0.68$; $p \leq 0.001$). Likewise, sweetness and aroma showed a high linear correlation ($|r| = 0.44$; $p \leq 0.01$). A similar result was already observed [30, 31], while Infante et al.[32] found a high correlation between sweetness and aroma for preconditioned peaches assessment on fruit maintained in cold storage. However, this correlation did not match with acceptability.

Moreover, sweetness had high positive correlation also with fibrousness, intensity of smell, bitterness, and negative with juiciness. Aroma, as well, was negatively correlated with juiciness, that is considered a negative attribute for panel liking.

Sourness was correlated only with texture attributes, positively with hardness and juiciness, and negatively with fibrousness.

3.5. Relationships between the sensory and physical and chemical attributes

The relationships between sensory and physical and chemical attributes was studied by linear regression analysis. Correlation matrix of all the data set was reported in Table 3. In order to have a simpler correlation matrix, only sensory data were correlated with physical and chemical data [21] and with some indexes: a*/b* ratio [1]; sucrose/(glucose + fructose); malic acid/citric acid; total sugars/total organic acids [6].

Fibrousness is positively correlated with background skin color a*, background skin a*/b*, weight, pulp pH, SSC/TA, malic acid/citric acid, and total sugars/total organic acids. These data confirmed the positive correlation between fibrousness and sweetness, as well as the negative correlation between fibrousness and sourness. As expected, hardness is positively correlated with pulp firmness, but also with malic acid, sucrose, sucrose/(glucose + fructose), as a consequence of the fact that hardness is a ripeness attribute. The third texture attribute, juiciness, is mainly correlated with the same parameters listed for hardness but with opposite sign.

Intensity of smell, unexpectedly, showed negative correlations with the main volatiles, expressed as odor activity values (OAV), as well as the total lactone OAV. This behavior is hard to explain, even if it is well-known that odour intensity and concentration are not always positively correlated (saturation). In addition, intensity of smell did not show any statistical difference among the four landraces. Moreover, this parameter is highly correlated with all the acidity parameters and with background skin color a*, indicating a positive relationship between the unripeness and smell. However, this anomalous behavior was already reported by Peano et al. [4] and ascribed to the panel.

Sweetness is highly correlated with °Brix, sucrose, total sugars, total sugar content corrected with the relative sweetness for each carbohydrate [33], and sucrose/(glucose + fructose), malic acid, and pulp color a*/b*, showing as the panel attributed the highest scores to the fruits with highest sugar content and ripeness. A positive correlation was recorded also between sucrose and phenolics.

Sourness is negatively correlated with pulp pH, SSC/TA, malic acid/citric acid, total sugars/total organic acids, while it is positively correlated with titratable acidity, citric acid, and pulp hydroxycinnamic acids. These results indicated as this attribute was evaluated in an unequivocal way by the panel.

An interesting positive high correlation is showed between bitterness, phenolics, and lactone OAV. Flavan-3-ols are responsible for bitterness and astringency [34], and hydroxycinnamic acids show a bitter-sour taste [35]. Lactones, as well, are described as bitter substances. The bitter thresholds for γ- and δ-decalactone are 340 and 420 μmol/l, respectively. Independently from the γ- or δ-lactone ring, the threshold for bitterness increases with an elongation of the aliphatic chain [36].

Overall liking is correlated with the main ripeness parameters, positively with background skin a*/b*, weight, malic acid/citric acid, sucrose/(fructose + glucose), and negatively with citric acid, fructose. Overall liking, as well as aroma, is positively correlated with pulp firmness, once again confirming the assumption that the firmness of the fruit at ripe stage is not only suitable for transport, but also associated with sugar and acid content typical of fresh-market quality peaches.

4. Conclusion

This paper reported the first detailed study on sensory profile of the four landraces of *Pescabivona* obtained by a trained panel of judges. The data obtained contribute to outline a complete fruit profile for product comparison and shelf-life monitoring.

Many analytical parameters are correlated with the sensory attributes, and for this reason sensory evaluation is a precious tool to asses quality of *Pescabivona*.

Finally, the results so far obtained support the study of local germplasm as a source of valuable quality features, with positive effect on local economy and agroecosystem.

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Table 1

Sensory analysis on sliced fruits of the four landraces expressed as the mean values (± SD). Results of the ANOVA are reported as F_{value} ***$p \leq 0.001$; **$p \leq 0.01$; *$p \leq 0.05$; n.s. = not significant.

		MURTIDDARA	BIANCA	AGOSTINA	SETTEMBRINA	ANOVA
Fibrousness	mean	2.42^{b}	3.08^{ab}	4.33^{a}	3.75^{ab}	**
	± SD	0.76	1.77	1.15	1.20	
Hardness	mean	3.33	3.29	3.33	4.04	n.s.
	± SD	0.96	1.03	0.65	1.14	
Juiciness	mean	5.38^{a}	4.63^{ab}	4.33^{ab}	3.83^{b}	**
	± SD	1.05	0.74	1.23	0.39	
Intensity of smell	mean	7.04	6.50	6.13	6.54	n.s.
	± SD	0.69	1.09	1.42	1.29	
Sweetness	mean	5.88^{b}	6.42^{ab}	6.38^{ab}	7.04^{a}	*
	± SD	0.80	1.04	0.88	0.69	
Sourness	mean	4.38^{a}	4.08^{ab}	2.12^{b}	3.16^{ab}	**
	± SD	1.21	1.53	1.51	1.60	
Bitterness	mean	0.50^{b}	2.63^{a}	0.71^{b}	1.83^{ab}	***
	± SD	0.83	1.42	0.81	0.83	
Aroma	mean	6.29^{ab}	5.54^{b}	6.46^{ab}	7.33^{a}	***
	± SD	0.54	1.56	0.84	0.62	
Overall liking	mean	6.21^{b}	6.17^{b}	6.96^{ab}	7.29^{a}	**
	± SD	1.16	0.83	0.62	0.45	
Pulp ground color		White 100 %	White 100 %	White 100 %	White 100 %	
Presence of red veins		27 % Present 73 % Absent	100 % Present	100 % Present	92 % Present 8 % Absent	

Table 2

Correlation matrix of the sensory analysis data set. Correlation coefficient (r) with $p \leq 0.05$, **$p \leq 0.01$**, **$p \leq 0.001$** are reported.

	Fibrousness	Hardness	Juiciness	Intensity of smell	Sweetness	Sourness	Bitterness	Aroma	Overall liking
Fibrousness									
Hardness									
Juiciness	**-0.54**								
Intensity of smell									
Sweetness	**0.45**		**-0.41**	**0.37**					
Sourness	-0.35	0.32	0.36						
Bitterness					**0.37**				
Aroma			-0.30		**0.44**				
Overall liking					**0.48**			**0.68**	

Table 3

Correlation between sensory values and chemical and physical parameters. Correlation coefficient (r) with p ≤ 0.05, **p ≤ 0.01**, **p ≤ 0.001** are reported.

	Fibrousness	Hardness	Juiciness	Intensity of smell	Sweetness	Sourness	Bitterness	Aroma	Overall liking
Background skin color L*			-0.555		0.690		**0.777**		
Background skin color a*	**0.839**		-0.617	**-0.852**		**-0.810**			
Background skin color b*									
Background skin a*/b*	**0.861**		-0.669	**-0.863**		**-0.822**			0.597
Skin over color L*	-0.691		0.672	0.578		0.657			-0.702
Skin over color a*							0.593		
Skin over color b*				**0.718**					
Skin over color a*/b*									
Pulp color L*		**-0.836**	**0.732**		**-0.870**		-0.604		
Pulp color a*					0.654		0.595		
Pulp color b*				-0.587					
Pulp color a*/b*			**-0.726**		**0.771**		0.648		
Percentage of red				0.640			-0.585		
Weight	**0.759**	0.618	**-0.930**	-0.686	**0.883**	-0.619			**0.759**
Pulp firmness		**0.782**						**0.752**	0.608
Pulp pH	**0.794**		-0.596	**-0.883**		**-0.726**			
Brix°			**-0.806**		**0.874**		**0.853**		
Titratable acidity	-0.697			**0.730**		**0.783**			
SSC/TA	**0.904**			**-0.938**		**-0.903**			
Citric acid	**-0.965**		**0.765**	**0.968**		**0.914**			-0.672
Malic acid		**0.850**	**-0.710**		**0.874**		0.668		
Quinic acid	**0.827**			**-0.864**		**-0.889**			
Succinic acid	0.581					**-0.712**	-0.582		
Total organic acids		0.671							
Malic acid/Citric acid	**0.926**		**-0.851**	**-0.848**	0.700	**-0.866**			**0.810**
Fructose		**-0.950**	**0.862**		**-0.919**			**-0.831**	**-0.867**
Glucose							**0.771**	**-0.752**	
Sucrose		**0.788**	**-0.712**		**0.858**		0.685		

Total sugars		0.665	-0.626		**0.782**		**0.778**		
Total sugar content corrected		0.616	-0.576		**0.736**		**0.786**		
Sucrose/(Fructose+Glucose)		**<u>0.961</u>**	**-0.779**		**<u>0.893</u>**			**0.767**	**0.742**
Total sugars/Total organic acids	**0.749**			**<u>-0.851</u>**		**-0.716**			
Pulp flavan-3-ols			-0.700		**0.747**		**0.816**		
Pulp Hydroxycinnamic acids						0.647	0.691	-0.652	-0.634
Pulp total phenolics			-0.612		0.676		**<u>0.850</u>**		
Pulp antioxidant capacity							**<u>0.849</u>**		
C10 γ-lactone OAV				-0.682			**0.773**		
C10 δ-lactone OAV							**<u>0.907</u>**		
C12 γ-lactone OAV	0.595			**-0.801**			0.601		
Total lactone OAV				**-0.754**			0.681		

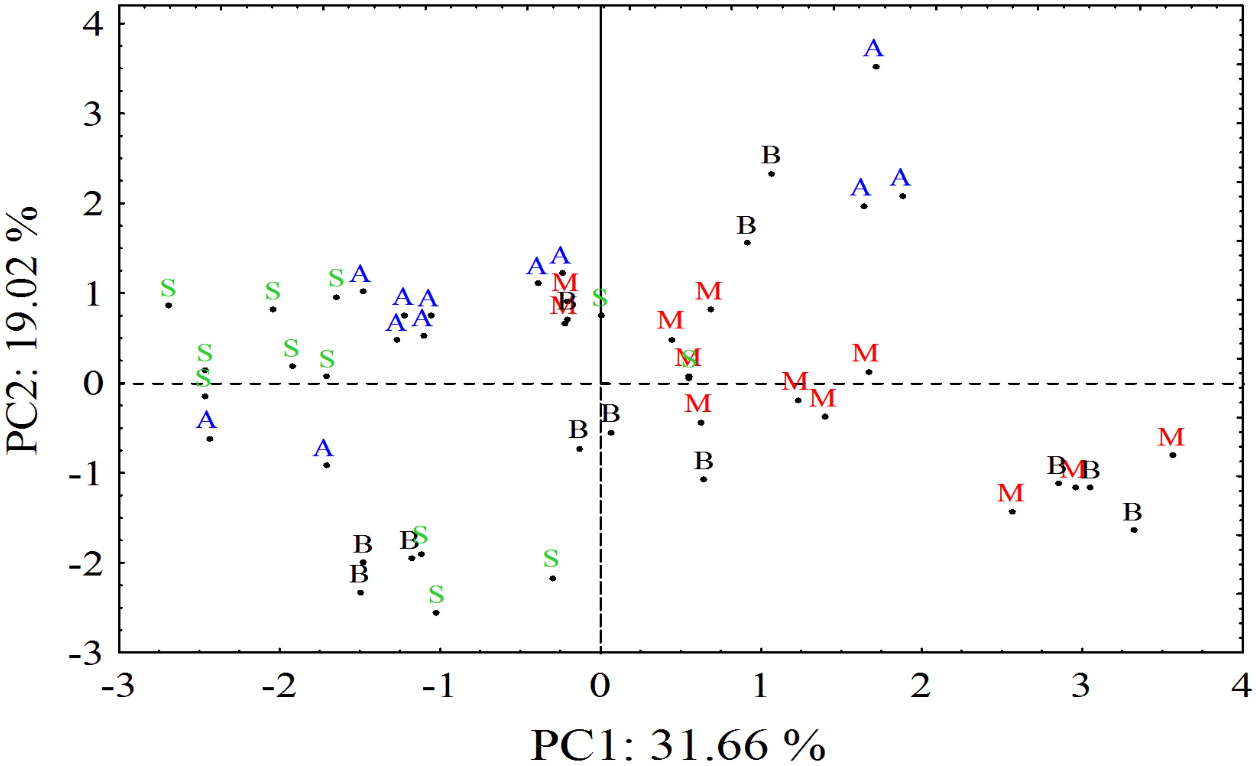

Fig. 1. Principal component analysis of replicated samples [M, Murtiddara; B, Bianca; A, Agostina; S, Settembrina]. Plot of the first two principal components (PC1 vs. PC2) with the explained variances.

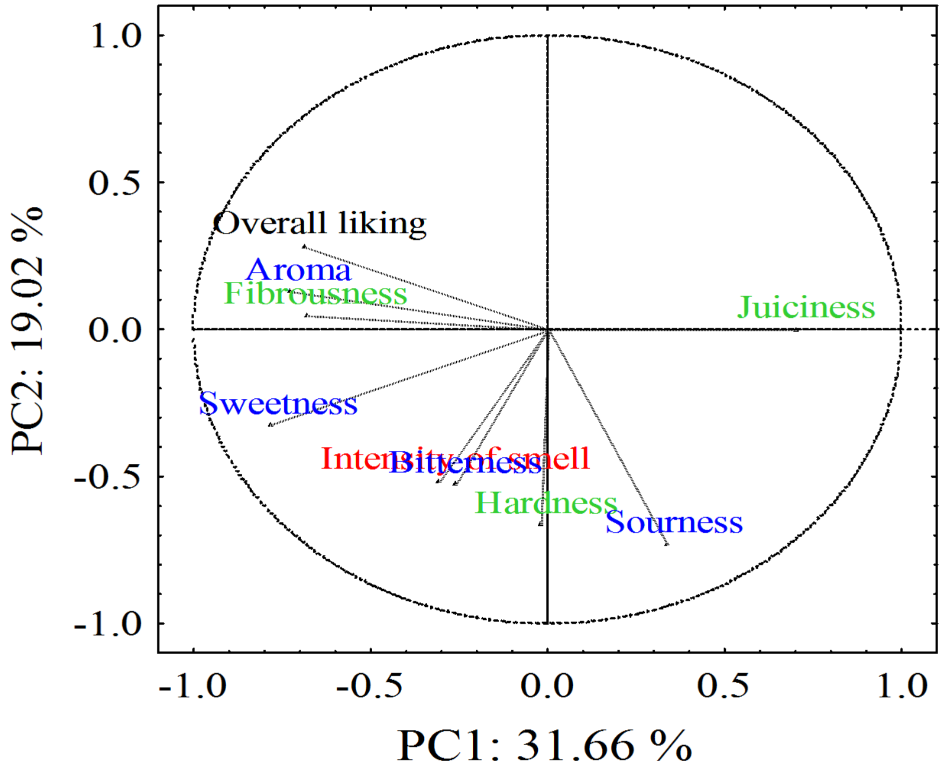

Fig. 2. Plot of the loading values loaded on the first and second component (PC1 vs. PC2) with the explained variances.

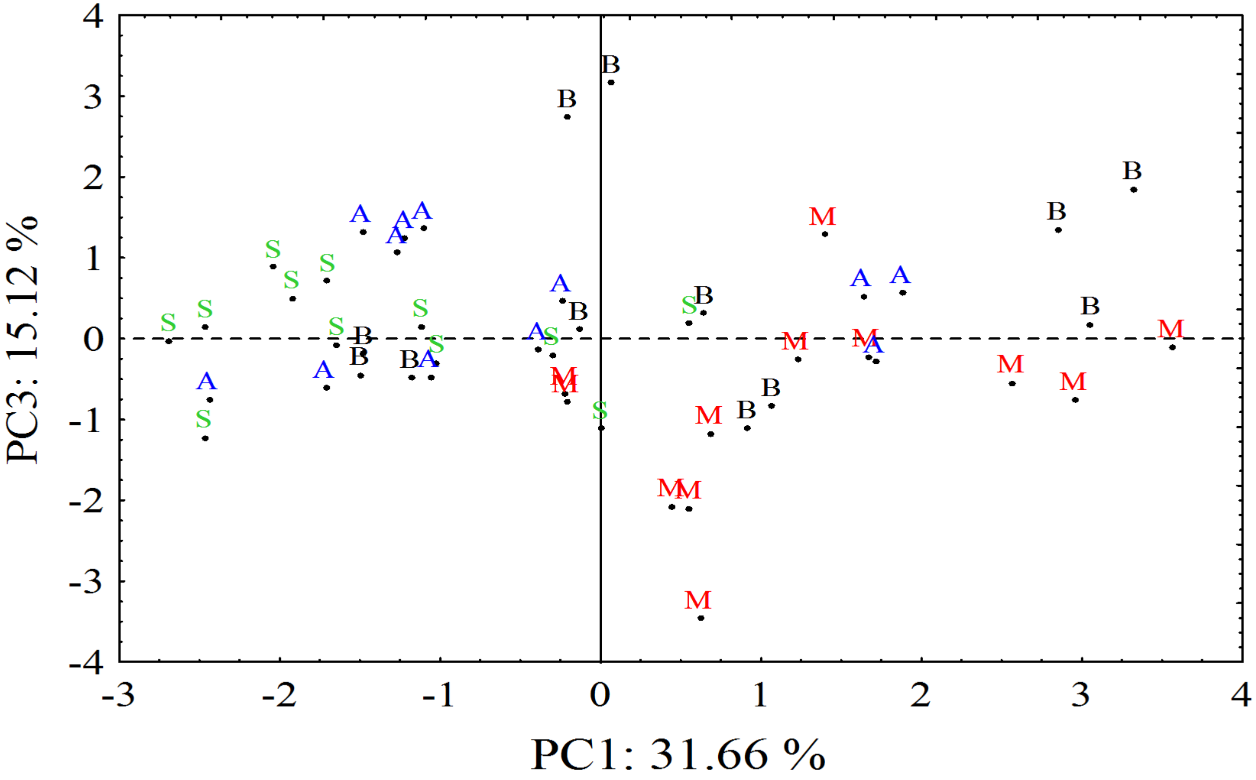

Fig. 3. Principal component analysis of replicated samples [M, Murtiddara; B, Bianca; A, Agostina; S, Settembrina]. Plot of the first and third principal components (PC1 vs. PC3) with the explained variances.